INDOOR AIR QUALITY ASSESSMENT

Early Learning Center
25 School Street
North Attleborough, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of the North Attleborough School Department (NASD), the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), has been conducting indoor air quality assessments in each of North Attleborough's public schools. These assessments were coordinated through Roland Deneault, Facilities Director for the NASD. On February 2, 2006, Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an indoor air quality assessment at the Early Learning Center (ELC), located at 25 School Street, North Attleborough, Massachusetts. Mr. Holmes was accompanied by Frank Caron, Head Custodian, during the assessment.

The ELC is a one-story, L-shaped, red brick building that was originally constructed as the School Street School in 1955. A one-classroom addition was made in the mid-1960s. The majority of building materials (e.g., floor tiles, heating and ventilation components, window systems) appear to be original. The building reportedly has had a history of roof leaks. Mr. Caron reported that the roof was repaired during the summer of 2005; no leaks have been reported since these repairs. Windows throughout the building are openable.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using an Hnu, Model 102 Snap-on Photo Ionization Detector (PID). MDPH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The ELC has approximately 30 staff members who provide early education to children between 3 and 5 years of age. Students attend either a morning or afternoon session. There are approximately 100 students in each session. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in all areas surveyed, indicating adequate air exchange. Fresh air in classrooms is supplied by a unit ventilator (univent) system (Pictures 1 and 2). Univents are designed to draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 3) and return air through air intakes located on the sides of each unit (Picture 1). Fresh and return air are mixed and filtered, then heated and provided to classrooms through an air diffuser located in the top of the unit (Figure 1). Univents have fan control speeds of low, medium or high (Picture 4). All univents were operating and appeared to be in good working order during the assessment. Obstructions to airflow, such as papers and books stored on univents and furniture in front of univent returns, were seen in several classrooms (Picture 5). In order for univents to provide fresh air as designed, they must remain free of obstructions.

The mechanical exhaust ventilation system in classrooms consists of wall mounted vents (Picture 6) connected to rooftop motors (Pictures 7 and 8). This system was also operating in all areas during the assessment. As with the univents, obstructions to airflow were seen in several classrooms (Picture 6).

Mechanical ventilation for the former cafeteria, which is currently used as an occupational/physical therapy area, is provided by air handling units (AHUs) located in mechanical rooms on either side of the stage. Fresh air is distributed via wall-mounted supply vents and air is returned to the AHUs through a return vent below the stage (Picture 9). The speech and PT offices are not equipped with mechanical ventilation or openable windows, therefore have no means of air exchange.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools because a majority of occupants is young and considered a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 69^{o} F to 74^{o}F, with all but one area within the MDPH recommended comfort guidelines during the assessment. The MDPH recommends that indoor air temperatures be maintained in a range of 70^{o}F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. To provide cooling during spring/summer months, the majority of classrooms are equipped with window-mounted air conditioners. Air conditioning for classrooms 3 and 5 is provided by a ducted rooftop AHU (Pictures 10 and 11).

The relative humidity measurements ranged from 23 to 29 percent, below the MDPH recommended comfort range in all areas surveyed the day of the assessment. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As discussed, the roof was repaired during the summer of 2005. Ceiling tiles damaged from historic water leaks were observed in a number of areas. Water damaged ceiling tiles can provide a source of mold growth and should be replaced after a water leak is discovered and repaired. However, ceiling tiles at the ELC are adhered (glued) directly to the ceiling matrix; therefore, removal of the tiles is difficult, because it requires destruction of the damaged tiles. Tile removal should be considered a renovation project.

Although the roof was recently repaired, it was not re-graded to improve drainage. MDPH staff observed conditions on the roof and found large areas of pooling water (Pictures 7, 10 and 12). The freezing and thawing of water during winter months can lead to roof leaks and subsequent water penetration into the interior of the building.

Another potential pathway for water penetration into the building is around univent air intakes on the exterior of the building. Missing/damaged caulking was observed around univent air intakes (Picture 13). Repeated water penetration can result in the chronic wetting of building materials and potentially lead to microbial growth. In addition, these breaches may provide a means of egress for pests/rodents into the building.

Spaces between the sink countertop and backsplash were seen in a few classrooms (Table 1/Picture 14). Improper drainage or sink overflow can lead to water penetration of countertop wood, the cabinet interior and areas behind cabinets. Like other porous materials, if these materials become wet repeatedly, they can provide a medium for mold growth.

Plants were noted in several classrooms. Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen, or mold.

Other IAQ Evaluations

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion products include carbon monoxide, carbon dioxide, water vapor, and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. For the ELC, indoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured outside the school were also ND (Table 1). Although no measurable levels of carbon monoxide were detected, a potential source was identified outside the boiler room. During a perimeter inspection of the building MDPH staff observed a breach in the exhaust ductwork for the hot water heater (Pictures 15 and 16). This section of ductwork should be repaired to ensure proper removal of exhaust emissions.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 μg/m^3 over a 24-hour average (Us EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 19 μg/m^3 (Table 1). PM2.5 levels measured indoors ranged from 7 to 17 μg/m^3 (Table 1). All measurements were below the NAAQS of 65 μg/m^3. Frequently, indoor air levels of particulates (including PM2.5) can be higher than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Indoor TVOC measurements throughout the building were ND (Table 1). Outdoor TVOC concentrations were also ND (Table 1). Please note that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases, and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Conclusions/Recommendations

Although no evidence of current roof leaks or complaints of poor ventilation/airflow were reported, the conditions of water pooling on the roof and the age of ventilation equipment may pose issues in the future. The issues identified during the assessment, when combined, can serve to degrade indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for immediate implementation:

1. Relocate or provide mechanical ventilation for the speech and PT offices.
2. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
3. Use openable windows in conjunction with classroom univents and exhaust vents to increase air exchange as needed. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.

4. Consider having ventilation systems re-balanced/calibrated every five years by an HVAC engineering firm.

5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

6. Avoid over-watering of plants and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.

7. Seal breaches around univent fresh air intakes to prevent water penetration, drafts and pest entry.

8. Seal breach or replace damaged section of exhaust ductwork for the water heater (Pictures 15 and 16).

9. Seal areas around sinks to prevent water-damage to the interior of cabinets and adjacent wallboard. Inspect wallboard for water damage and mold growth, repair/replace as necessary. Disinfect areas with an appropriate antimicrobial, as needed.

10. Change filters for air-handling equipment (i.e., univents, AHUs, window mounted ACs) as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces in between allowing bypass of unfiltered air into the unit.

11. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
12. Consider adopting the US EPA document, "Tools for Schools", to maintain a good indoor air quality environment on the building (USEPA, 200b). This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.
13. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at. http://mass.gov/dph/indoor_air

The following **long-term measures** should be considered:

1. Consider consulting a building engineer about possible options to eliminate water pooling on roof.
2. Consider replacement of fixed ceiling tiles system with a dropped ceiling tile system.
3. Consider contacting an HVAC engineering for an evaluation of ventilation equipment to determine the operability and feasibility of repairing the equipment (as compared to replacing equipment).

References

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

US EPA. 2000a. National Ambient Air Quality Standards (NAAQS). . US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

US EPA. 2000b. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/tools4s2.html

Picture 1

Classroom Univent 1950's Vintage, Note Return Vents on Sides of Unit

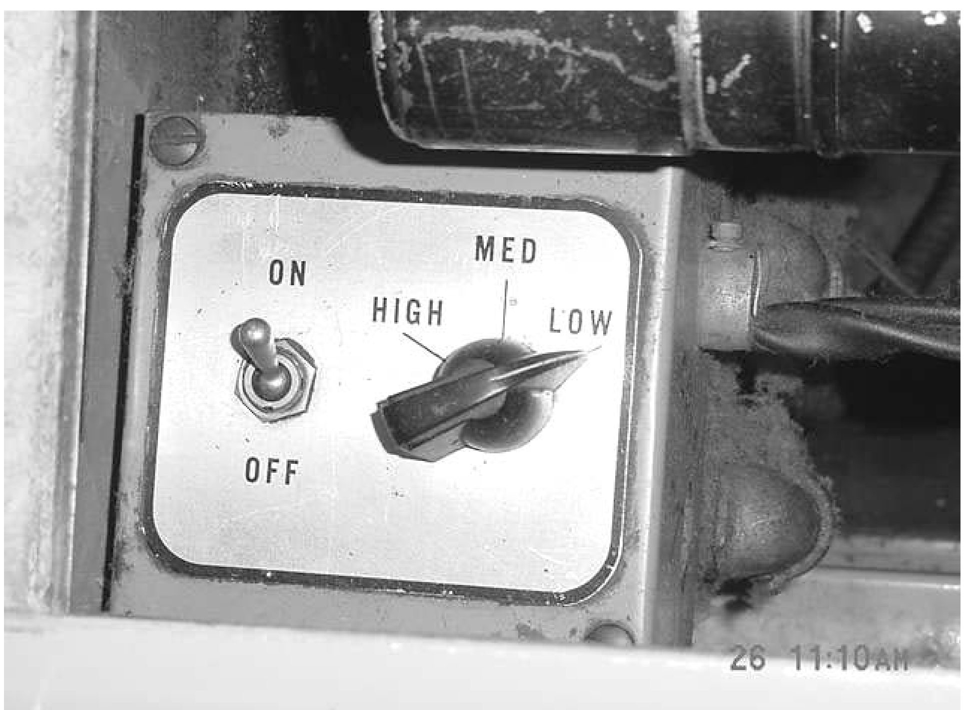
Picture 2

1960's Era Univent in Addition

Picture 3

Univent Fresh Air Intake

Picture 4



Univent Control Settings

Picture 5

Classroom Furniture and Items Obstructing Univent, Located against Exterior Wall

Picture 6

Partially Obstructed Exhaust Vent in Classroom

Picture 7

Rooftop Exhaust Vents for 1950's Building, also Note Water Pooling on Roof

Picture 8

Rooftop Exhaust Vent for 1960's Addition

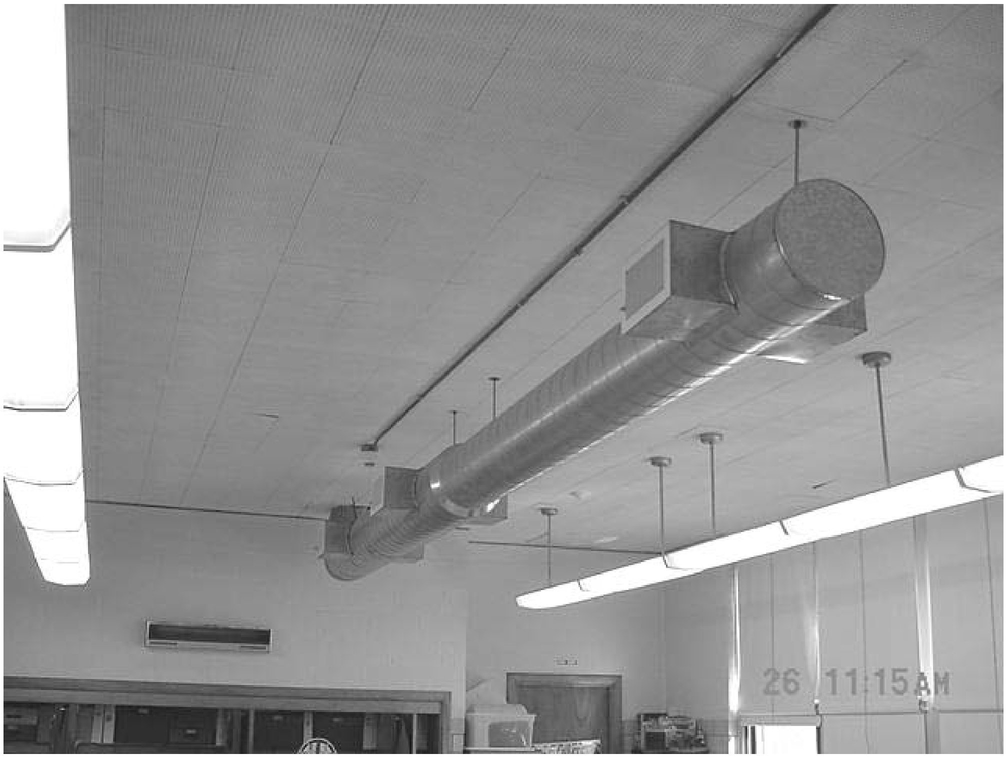
Picture 9

Wall-Mounted Supply Vents on Either Side of Stage

Picture 10

Rooftop AC/AHU for Interior Classrooms, also Note Water Pooling on Roof

Picture 11



Ductwork Connected to Rooftop AHU in Picture 10

Picture 12

Large Areas of Water Pooling on Roof

Picture 13

Missing/Damaged Caulking around Univent Fresh Air Intakes

Picture 14

Spaces between Sink Countertop and Backsplash

Picture 15

Water Heater in Boiler Room

Picture 16

Breach in Bottom of Water Heater Exhaust Duct

Early Learning Center **Indoor Air Results**

25 School Street, North Attleborough, MA **Table 1** **January 26, 2006**

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (outdoors)	38	33	372	ND	ND	19					Atmospheric Conditions: cold, dry, scattered clouds, NW winds 20-25 mph
Gym: OT/PT	70	26	415	ND	ND	13	0	Y	Y	Y	2 AHUs, windows reportedly difficult to open
Teachers Lounge	71	26	431	ND	ND	12	0	Y	N	N	Window-mounted AC
1	73	25	598	ND	ND	12	10	Y	Y	Y	UV and exhaust vent obstructed by items/furniture, WD CTs, Window-mounted AC
2	72	23	507	ND	ND	11	5	Y	Y	Y	WD CTs, Window-mounted AC
3	74	26	664	ND	ND	10	17	N	Y	Y	Ducted AC (rooftop), WD CTs
4	73	25	608	ND	ND	15	4	Y	Y	Y	DO, 17 occupants gone 5 mins, exhaust vent obstructed by furniture, Window-mounted AC

ppm = parts per million parts of air
CT = ceiling tile
AD = air deodorizer
AP = air purifier
CD = chalk dust

µg/m3 = microgram per cubic meter
WD = water damage
DEM = dry erase marker
DO = door open
PC = photocopier

UV = univent
CF = ceiling fan
PF = personal fan
TB = tennis balls
UF = upholstered furniture

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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5	71	26	570	ND	ND	16	3	Y	Y	Y	DO, ducted AC (rooftop), UV obstructed by furniture
Nurse's Office	72	26	573	ND	ND	9	0	Y	N	N	Window-mounted AC
Main Office	73	27	601	ND	ND	9	1	Y	N	N	Window-mounted AC, photocopier, DO
Resource Room	73	26	554	ND	ND	7	1	Y	N	N	Window-mounted AC, plants
7	70	26	773	ND	ND	10	9	Y	Y	Y	Window-mounted AC, breach sink/countertop
Coblentz Office	69	25	559	ND	ND	17	0	N	N	Y	WD CTs
6	72	26	590	ND	ND	12	19	Y	Y	Y	Window-mounted AC

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PT Office	71	29	773	ND	ND	11	1	N	N	N	Recommend mech. vent to provide air exchange, DO
Speech	71	27	626	ND	ND	10	0	N	N	N	Recommend mech. vent to provide air exchange, DO
Perimeter Notes											Water Heater exhaust duct damaged, missing damage around UV air intakes

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